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NEAR-INFRARED ABSORBENT GREEN GLASS COMPOSITION AND LAMINATED GLASS USING THE SAME

5 TECHNICAL FIELD

The present invention relates to a near-infrared absorbent green glass composition having a high visible light transmittance, a high infrared absorption capacity and an excellent effect of reducing thermal feeling, and to a laminated glass using this green glass composition.

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BACKGROUND ART

Most of the glass sheets for vehicles and buildings are manufactured by a float process, and the glass sheets are called soda-lime-silica glasses due to their basic components. For a window opening for a vehicle and a building, from the viewpoint of the energy saving, an infrared absorbent glass is required. For improving the infrared absorption capacity of the soda-lime-silica glass, an absorption by ferrous oxide (FeO) is utilized.

In addition to the absorption of infrared radiation, the window glass is required to absorb ultraviolet radiation, while required to have a high transmittance of visible light. In particular, with respect to the window glass for a vehicle such as a passenger car, a visible light transmittance to be achieved, which depends on its specific location, is regulated by law in order to ensure visibility. Although the visible light transmittance to be achieved differs country by country, the typical standard is 70% or more.

25 An infrared and ultraviolet absorbent soda-lime-silica green glass containing about 0.51 to 0.96% by weight Fe_2O_3 , about 0.15 to 0.33% by weight FeO and about 0.2 to 1.4% by weight CeO_2 has been disclosed in JP-A-3-187946. This glass sheet has a visible light transmittance of 70% or more when it has a thickness of about 3 to 5mm.

30 Infrared and ultraviolet absorbent soda-lime-silica green glasses have been disclosed also in JP-A-4-231347 and JP-A-6-166536.

35 On the other hand, a technique to absorb infrared radiation with functional fine particles dispersed in an interlayer film of a laminated glass without relying on glass components has been proposed. A laminated glass using an interlayer film in which ITO (conductive tin-containing indium oxide) ultra-fine particles having a particle size of $0.1\mu m$ or less are dispersed has been disclosed in JP-A-8-259279. This laminated glass

reduces scattering of visible light since the size of the ITO fine particles is small.

DISCLOSURE OF THE INVENTION

Reducing the thermal feeling that people feel on their skin caused by sunlight that transmits through the glass is effective to improve comfort in cars or rooms. Although the laminated glass described in JP-A-8-259279 using the interlayer film in which the ITO fine particles are dispersed has an excellent effect of reducing the thermal feeling, the production cost thereof is high since the expensive ITO fine particles are required. In addition, although the ITO fine particles can be applicable to the laminated glass using the interlayer film, application to a single plate is difficult.

A transmittance in the wavelength region of 1100 to 2200 nm greatly affects the thermal feeling, and FeO has an absorption in the wavelength region of 550 to 1600 nm. Thus, in order to reduce the thermal feeling without using the ITO fine particles, it is preferable that the content of FeO in the glass be increased. However, FeO has an absorption even in a visible range and therefore, when the content of FeO simply is increased, the glass sheet is tinged with blue since the visible light transmittance is decreased and the dominant wavelength shifts to the shorter wavelength. As described above, there is the regulation of the visible light transmittance corresponding to the location in the vehicle in which the glass is used. In addition, the mainstream of the color tone of the window glass is green. Therefore, when the content of FeO simply is increased, even though the thermal feeling is reduced, the application of the glass is limited.

Accordingly, it is an object of the present invention to provide a useful near-infrared absorbent glass composition capable to reduce the thermal feeling. It is another object of the present invention to provide a useful near-infrared absorbent glass composition capable of reducing the thermal feeling, particularly having a small thickness, and further to provide a laminated glass using this composition.

A near-infrared absorbent green glass composition of the present invention contains, in mass %, 65 to 80% SiO₂, 0 to 5% B₂O₃, 0 to 5% Al₂O₃, 0 to 10% MgO, 5 to 15% CaO, 10 to 18% Na₂O, 0 to 5% K₂O, 0 to 2% TiO₂, 0.05 to 0.5% SO₃, 0.6 to 1.3% total iron oxide amount in terms of Fe₂O₃ (hereinafter, referred to as “T-Fe₂O₃”), 0 to 2.0% CeO₂ and, in mass ppm, 300 ppm or less MnO. In addition to that, a total content of MgO and CaO

is from 5 to 20 mass %, a total content of Na_2O and K_2O is from 10 to 20 mass %, and a mass ratio (hereinafter referred to as "FeO ratio") of FeO converted into Fe_2O_3 relative to the $\text{T}\text{-}\text{Fe}_2\text{O}_3$ is from 0.21 to 0.35. The near-infrared absorbent green glass composition of the present invention 5 satisfies at least one of the following a) and b):

a) when the near-infrared absorbent green glass composition is formed to have a thickness in the range of 1.3 to 2.4mm, a visible light transmittance measured by using CIE illuminant A is at least 80%, a total solar energy transmittance is 62% or less, a dominant wavelength measured by using 10 CIE illuminant C is from 500 to 540 nm, and an integrated value obtained by integrating transmittances of every 1 nm in the wavelength from 1100 to 2200 nm is 62000 or less;

b) when the near-infrared absorbent green glass composition is formed to have a thickness in the range of 3 to 5mm, a visible light transmittance 15 measured by using CIE illuminant A is at least 70%, a total solar energy transmittance is 45% or less, a dominant wavelength measured by using CIE illuminant C is from 495 to 540 nm, and an integrated value obtained by integrating transmittances of every 1 nm in the wavelength from 1100 to 2200 nm is 62000 or less.

20 If the above-mentioned integrated value is 62000 or less, the thermal feeling caused by the sunlight that transmits through the glass is reduced greatly.

When the present invention is applied, the glass composition can be provided which can satisfy a wide variety of required properties even though 25 it has a relatively small plate thickness, for example, the range of 1.3 to 2.4mm. According to the research of inventors of the present invention, the smaller the thickness of the glass sheet is, the more difficult it is to achieve other optical properties in the practical level while still reducing the thermal feeling. However, the inventors found that the above object can be 30 achieved by treating $\text{T}\text{-}\text{Fe}_2\text{O}_3$ as a function of the thickness of the glass sheet. When the near-infrared absorbent green glass composition of the present invention is formed to have a thickness t (mm) of 1.3 to 2.4mm, it is preferable that TFe (mass %), which is the content of $\text{T}\text{-}\text{Fe}_2\text{O}_3$, be in the range expressed by equation (1), and that the FeO ratio be from 0.275 to 35 0.35.

$$1.8 \cdot 0.5t \leq \text{TFe} \leq 1.9 \cdot 0.5t \quad (1)$$

Moreover, it is preferable that TCe (mass %), which is the content of

CeO_2 , be 0 or more and in the range expressed by equation (2).

$$t \cdot 1.8 \leq \text{TCe} \leq t \cdot 0.8 \quad (2)$$

According to the present invention, the near-infrared absorbent green glass composition is provided that can reduce the thermal feeling and has a green color tone and a high infrared absorption capacity while retaining a high transmittance in a visible range even in a small thickness region.

BEST MODES OF EMBODIMENTS OF THE INVENTION

Hereinafter, the contents of components expressed in % and ppm are all calculated on a mass basis.

In the near-infrared absorbent green glass composition of the present invention, the FeO ratio is preferably from 0.26 to 0.35. Moreover, MnO may be contained as an essential component. In this case, the content is preferably from 30 to 300 ppm.

As an example of the near-infrared absorbent green glass composition of the present invention, the content of $\text{T-Fe}_2\text{O}_3$ is from 0.60 to 0.77% and the content of CeO_2 is from 0.55 to 2.0%. In another example, the content of CeO_2 is from 0.1 to 2.0 and the FeO ratio is more than 0.275 and not more than 0.35. In yet another example, the content of CeO_2 is from 0.1 to 1.4%. In still yet another example, the FeO ratio is more than 0.29 and not more than 0.35. In an example other than the above examples, the content of CeO_2 is from 0.65 to 2.0%.

In the near-infrared absorbent green glass composition of the present invention, the content of $\text{T-Fe}_2\text{O}_3$ may be from 0.70 to 0.77%, the FeO ratio may be from 0.275 to 0.35, and the content of CeO_2 may be from 0.65 to 1.4%. This composition is suitable for the use with the embodiment wherein the glass composition is formed to have a thickness in the range of 2.1 to 2.4 mm.

In the near-infrared absorbent green glass composition of the present invention, the content of $\text{T-Fe}_2\text{O}_3$ may be from 0.78 to 0.90%, the FeO ratio may be from 0.265 to 0.30, and the content of CeO_2 may be from 0.65 to 0.90%. This composition is suitable for the use with the embodiment wherein the glass composition is formed to have a thickness in the range of 2.0 to 2.2 mm.

In the near-infrared absorbent green glass composition of the present invention, the content of $\text{T-Fe}_2\text{O}_3$ may be from 0.77 to 0.80%, the FeO ratio may be from 0.30 to 0.35, and the content of CeO_2 may be from 0.65 to 1.0%.

This composition also is suitable for the use with the embodiment wherein the glass composition is formed to have a thickness in the range of 2.0 to 2.2 mm.

In the near-infrared absorbent green glass composition of the present invention, the content of T- Fe_2O_3 may be more than 0.90% and not more than 0.98%, the FeO ratio may be from 0.21 to 0.28, and the content of CeO_2 may be 0.50% or more. This composition is suitable for the use with the embodiment wherein the glass composition is formed to have a thickness in the range of 1.7 to 1.9 mm.

In the near-infrared absorbent green glass composition of the present invention, the content of T- Fe_2O_3 may be from 0.98 to 1.3%, and the FeO ratio may be from 0.275 to 0.35. This composition is suitable for the use with the embodiment wherein the glass composition is formed to have a thickness in the range of 1.3 to 1.8 mm.

Use of the near-infrared absorbent green glass composition of the present invention can achieve the ultraviolet transmittance of 42% or less, preferably 40.5% or less in the case of at least one of the above a) and b), and achieve the ultraviolet transmittance of 40% or less even if the glass composition of the present invention is formed to have a small plate thickness, for example a') the thickness in the range of 1.3 to 2.0 mm.

[Each component in the composition]

The reasons for the limitations of the glass composition of the present invention are explained below.

(SiO_2)

SiO_2 is a main component for forming the skeleton of glass. If the content of SiO_2 is less than 65%, the glass has poor durability. If the content thereof exceeds 80%, the glass is difficult to melt. Further, the content of SiO_2 is more preferably not less than 69% and less than 72%.

(B_2O_3)

B_2O_3 is not an essential component but a component used for improving glass durability or as a melting aid. B_2O_3 functions also to enhance ultraviolet absorption. If the content of B_2O_3 exceeds 5%, a decrease of the transmission in the ultraviolet region extends to the visible region so that the color tone of the glass tends to tint yellow. Moreover, the vaporization of B_2O_3 and the like causes inconvenience during the forming. Consequently, the upper limit of the content of B_2O_3 should be 5%. The preferable content of B_2O_3 is from 0 to 2%, excluding 2%.

(Al₂O₃)

Al₂O₃ is not an essential component but a component for improving glass durability. Therefore, it is preferable to add Al₂O₃ at the content of 1% or more. If the content of Al₂O₃ exceeds 5%, the glass is difficult to 5 melt. Further, since Al₂O₃ lowers a mean linear expansion coefficient so as to deteriorate the capability of tempering, the content of Al₂O₃ is preferably 2.5% or less.

(MgO)

MgO is not an essential component but used to improve glass 10 durability and adjust a liquidus temperature and viscosity of the glass during forming. In the present invention, the content of MgO is 10% or less. If the content of MgO exceeds 10%, the liquidus temperature rises. The preferable content of MgO is in the range of over 2% to 5%.

(CaO)

15 CaO is used to improve glass durability and adjust a liquidus temperature and viscosity of the glass during forming. If the content of CaO is less than 5%, the effects become low. If it exceeds 15%, the liquidus temperature rises.

It should be noted that if the total content of MgO and CaO is less 20 than 5%, the necessary amount of CaO can not be secured. Further, since in order to keep the liquidus temperature and viscosity of the glass during forming, addition of alkaline oxide is required, and it results in low glass durability. When the total content of MgO and CaO exceeds 20%, it is not preferable for the production of the glass since the liquidus temperature 25 rises and the density becomes high. The total content of MgO and CaO is more preferably less than 15%.

(SrO、BaO)

SrO and BaO are not essential components but can be added in order 30 to improve glass durability and adjust a liquidus temperature and viscosity of the glass during forming. Since SrO and BaO are expensive materials, it is not preferable that the content of each exceed 10%.

(Na₂O、K₂O)

Na₂O and K₂O, which are alkaline oxides, are used as glass melting accelerators.

35 If the content of Na₂O is less than 10% or if the total content of Na₂O

and K_2O is less than 10%, the efficiency of promoting melting becomes poor. If the content of Na_2O exceeds 18% or if the total content of Na_2O and K_2O exceeds 20%, glass durability is lowered.

It should be noted that Li_2O may be contained as an alkaline oxide. 5 Since Li_2O is a more expensive material than Na_2O , it is not preferable that the content of Na_2O exceed 5%.

(TiO_2)

TiO_2 may be added in a small amount to lower the liquidus temperature of the glass. TiO_2 is also a component for absorbing 10 ultraviolet radiation. If the content of TiO_2 is large, the glass tends to be tinted yellowish. Therefore, the upper limit of the content of TiO_2 should be 2%.

(SO_3)

SO_3 is a component that serves to accelerate refining of the glass. If 15 the content of SO_3 is less than 0.05%, a sufficient refining effect cannot be attained by a regular melting method. Conversely, if the content of SO_3 exceeds 0.5%, SO_2 , which is produced as a result of decomposition of SO_3 , remains in the glass in the form of a bubble, or bubbles are generated by reboiling. The preferable range of the content of SO_3 is from 0.05 to 0.25%.

20 (Iron oxide)

Iron oxide is present in the form of Fe_2O_3 and the form of FeO in the glass. Fe_2O_3 absorbs ultraviolet radiation and FeO absorbs infrared radiation.

25 $T \cdot Fe_2O_3$ is obtained by the conversion of the total amount of Fe_2O_3 and FeO into Fe_2O_3 , and the content of $T \cdot Fe_2O_3$ is selected in the range of 0.6 to 1.3%. A mass ratio of FeO converted into Fe_2O_3 relative to the $T \cdot Fe_2O_3$ is selected in the range of 0.21 to 0.35.

30 If the content of $T \cdot Fe_2O_3$ is less than 0.6%, a sufficient ultraviolet and infrared absorption effect can not be obtained. If the content of $T \cdot Fe_2O_3$ exceeds 1.3%, radiant heat from a flame is absorbed significantly at the upper part of the melted glass during melting of the glass material. It thus makes it difficult to heat the glass to near the bottom of the melting furnace during the melting of the glass sufficiently. Moreover, if the content of $T \cdot Fe_2O_3$ exceeds 1.3%, the density of the glass becomes too high.

35 If the FeO ratio is too low, the infrared absorption effect becomes insufficient. From this viewpoint, the FeO ratio is preferably 0.26 or more, more preferably 0.275 or more, particular preferably 0.29 or more. On the

other hand, if the FeO ratio is too high, a streak which is silica-rich or a silica scum is generated easily. Therefore, the FeO ratio is preferably 0.35 or less.

The contents of T·Fe₂O₃ and the FeO ratio should be adjusted properly, 5 depending on the thickness to be formed and the like, while other properties are taken into consideration.

(CeO₂)

CeO₂ is not an essential component but a component effective for ultraviolet absorption. In addition, CeO₂ is also an component effective to 10 adjust the color tone of the glass without reducing visible light transmittance.

If FeO, which absorbs infrared radiation, is increased and Fe₂O₃ is decreased relatively, the color tone of the glass tends to tint blue. In order to retain green color tone without decrease of visible light transmittance, CeO₂ 15 may be added as an essential component. If the content of CeO₂ is 0.1% or more, preferably 0.65% or more, high ultraviolet absorption capability can be obtained. CeO₂ is an expensive material and if this is taken into consideration, the upper limit of the content of CeO₂ is preferably 2%, more 20 preferably 1.4%. In this regard, the content of CeO₂ also should be adjusted properly, depending on the thickness to be formed and the like, while other properties are taken into consideration.

(MnO)

MnO is not an essential component but may be added in a small amount. In this glass composition, Fe₂O₃ and FeO are contained and CeO₂ also may be contained at the same time. Therefore, MnO may be added at the content of 25 30 ppm or more since MnO is an important and effective component to adjust the color tone of the glass and FeO ratio. However, the upper limit of the content of MnO should be 300 ppm, since the effect of tinting (solarization) by MnO itself emerges when the content of MnO becomes high.

(Other minor component)

30 The near-infrared absorbent green glass composition of the present invention may contain other minor components besides the above components. As the minor component, NiO, Cr₂O₃, Mo₂O₃, ZnO, SnO₂, and La₂O₃ are exemplified. The total content of the minor components is 10% or less, preferably 5% or less, more preferably 2% or less. It should be note that the 35 more preferable upper limits of the above minor components are 0.01% for NiO, Cr₂O₃ and Mo₂O₃, 0.1% for ZnO, and 1% for SnO₂ and La₂O₃.

[Optical property; Relationship between optical property and thermal feeling]

With respect to the near-infrared absorbent green glass composition of the present invention, the visible light transmittance and the dominant wavelength is set within the practically desirable range mainly by adjusting the contents of T- Fe_2O_3 , CeO_2 and MnO , and FeO ratio. In addition, in the preferable embodiment, preferable optical properties such as low ultraviolet transmittance are acquired by adjusting the above contents properly while taking the thickness to be formed into account.

Further, in the near-infrared absorbent green glass composition of the present invention, transmittance in the wavelength of 1100 to 2200 nm is lowered. There is a correlation between the transmittance in this wavelength region, specifically the integrated value obtained by integrating the transmittances (%) of every 1 nm in wavelength from 1100 to 2200 nm, and the thermal feeling that people feel on their skin. In other words, the greater the above-mentioned integrated value is, the stronger the thermal feeling is. This integrated value can be a better indicator for showing the extent of the thermal feeling as compared with other optical properties such as total solar energy transmittance.

[Transmittance for thermal feeling]

As explained above, in order to describe the relationship between the optical property and the thermal feeling, evaluation using the transmittance in the wavelength of 1100 to 2200 nm is appropriate. Moreover, for the finer evaluation, transmittance for thermal feeling is defined as below.

(Relationship between rise in skin temperature and thermal feeling)

First, the relationship between a range of the rise in skin temperature by the incident sunlight and the thermal feeling that people feel on their skin was evaluated. The procedure for the evaluation was as follows. A filter was attached to light flux radiated from a xenon lamp (SERIC LTD.: XC-500E) to give an illuminant which has an equal to the energy distribution of sunlight. A panel having a hole with a diameter of 50 mm was placed at the point which was 416 mm away from the illuminant. A back of the subject's hand was placed at the hole on the other side of the illuminant, and the temperature of the back of the subject's hand was measured every 3 seconds using a thermo-viewer. The subject announced the thermal feeling on the five scales of (1) slightly warm, (2) warm, (3) slightly hot, (4) hot, and (5) very hot. With respect to the thermal feeling people feel, the results of the experiments performed on 81 subjects were summarized. As a result, the rise in skin temperature and the thermal feeling have a proportional relation, and 0.5°C

rise in skin temperature makes the thermal feeling go up by about one scale. Further, it is confirmed that people do not feel "very hot" when the range of the rise in skin temperature is 3.2°C or less.

(Sensitivity ratio for thermal feeling)

5 An extent of the rise in skin temperature depends on the wavelength of the sunlight. The extent of the rise in skin temperature depending on the wavelength is quantified as a coefficient at the wavelength (sensitivity ratio for thermal feeling; hereinafter referred to as "SRTF"). The SRTF in the wavelength region of 300 to 840 nm and the SRTF in the wavelength region of 10 840 to 1350 nm are reported to be 1.43 and 1, respectively, when the value of the SRTF in the wavelength region of 840 to 1350 nm is set to 1. However, with respect to the wavelength region of 1350 to 2500 nm, the SRTF is not reported although it greatly affects the thermal feeling. Therefore, the SRTF in this wavelength region was determined by an experiment performed using 15 the light of the wavelength region of 1350 to 2500 nm which was picked up by replacing the filter from the above illuminant. This experiment also performed by measuring the rise in the temperature of the back of the subject's hand. The SRTF in the wavelength region of 1350 to 2500 nm was 3.34. The SRTF in the wavelength region of less than 300 nm and the SRTF in the wavelength region of more than 2500 nm can be assumed to be substantially 0. 20 The sensitivity ratios for thermal feeling in each wavelength region are collectively shown in Table 1.

Table 1

Wavelength region / nm	Sensitivity ratio for thermal feeling
<300	0
300 to 840	1.43
840 to 1350	1
1350 to 2500	3.34
>2500	0

25 (Transmittance for thermal feeling)

When the product of the spectral transmittance of the glass sheet and the solar spectrum is weighted using the sensitivity ratio for thermal feeling shown in Table 1, the thermal feeling that people actually feel can be described with accuracy using the optical property of the glass sheet. Here, 30 "transmittance for thermal feeling (Ttf, Transmittance for thermal feeling)" is

defined by the following equation.

Equation 1

$$T_{tf} = \frac{\int_0^{\infty} I_{\text{sun}}(\lambda) \cdot T_{\text{glass}}(\lambda) \cdot SR(\lambda) d\lambda}{\int_0^{\infty} I_{\text{sun}}(\lambda) \cdot T_{\text{air}}(\lambda) \cdot SR(\lambda) d\lambda}$$

Here, $I_{\text{sun}}(\lambda)$ is the solar spectrum at Air mass 1.5 defined by ISO9845-1,
5 $T_{\text{glass}}(\lambda)$ is the spectral transmittance of the glass sheet, and $SR(\lambda)$ is the
sensitivity ratio for thermal feeling shown in Table 1. $T_{\text{air}}(\lambda)$ is the spectral
transmittance of air and here assumed to be 1 irrespective of the wavelength.

The relationship between the range of the rise in skin temperature by
the sunlight that transmits through the glass sheet and the transmittance for
10 thermal feeling defined by the above equation was confirmed by evaluating as
below. In the above-mentioned evaluation apparatus, a glass sheet or a
laminated glass was placed roughly at the midpoint of the illuminant and the
back of the subject's hand with a normal to a glass plane forming the angle of
30 degrees with a line connecting the illuminant and the back of the subject's
15 hand, and the range of the rise in skin temperature was measured. With
respect to the range of the rise in skin temperature, the results of the
experiments performed by 111 subjects were summarized. As a result, it is
confirmed that there is good correlation between the rise in skin temperature
20 and the transmittance for thermal feeling.

Moreover, as the result of the above research, it is found that in order to
not make people feel very hot, the window glass that makes the rise in skin
temperature 3.5°C or less should be used, that is to say, the transmittance for
thermal feeling (T_{tf}) of the glass sheet or the laminated glass used as a window
25 glass should be 44% or less, preferably 42% or less, more preferably 40% or
less.

[Laminated glass]

By using a glass sheet including the near-infrared absorbent green glass
composition of the present invention, a laminated glass can be composed.
This laminated glass may be produced according to the conventionally known
30 method.

For example, this laminated glass is formed by laminating at least two
glass sheets through a thermoplastic resin layer, and at least one of the glass
sheets is the near-infrared absorbent green glass composition of the present

invention. The at least two glass sheet constituting the laminated glass may include the near-infrared absorbent green glass composition of the present invention.

The laminated glass of the present invention preferably has a visible light transmittance measured by using CIE illuminant A of 70% or more and a total solar energy transmittance of 45% or less, and more preferably, the ratio of the above total solar energy transmittance relative to the above visible light transmittance is 0.60 or less. Further, the laminated glass of the present invention preferably has a transmittance at the wavelength of 1550 nm of 37% or less and the integrated value obtained by integrating transmittances of every 1 nm in the wavelength from 1100 to 2200 nm is preferably 34000 or less. Furthermore, the laminated glass of the present invention preferably has the transmittance for thermal feeling of 44% or less.

Hereinafter, the present invention is described in further detail with reference to examples thereof, but it should be noted that the following examples as well as the foregoing are merely illustrative examples of the preferable embodiments of the present invention.

Silica sand, dolomite, limestone, soda ash, mirabilite, potassium carbonate, carbon, iron oxide, titanium oxide, cerium oxide, and blast-furnace slag were blended according to composition of the glass shown in Tables 2 and 3 and the batch was obtained. The batch was melted in an electric furnace at 1450°C. After the batch was kept molten for 4 hours, the resultant molten glass was cast on a stainless-steel plate. After the glass sheet thus obtained was placed for 30 min in an annealing furnace wherein the temperature was kept at 650°C, the annealing furnace was turned off so that the glass sheet was annealed to room temperature. The annealed glass sheet was polished so as to have a prescribed thickness and subjected to various measurements.

The properties of each glass sheet measured are shown in Tables 2 and 3. It should be noted that the case where the total of the contents in the table is not 100% is caused by different significant digits being used.

In Tables 2 and 3, Y_A means the visible light transmittance measured by using CIE illuminant A, T_G means the total solar energy transmittance, D_w means the dominant wavelength measured by using CIE illuminant C, T_{UV} means the ultraviolet transmittance measured based on the solar spectrum with the energy distribution at Air mass 2, Pe means the excitation purity measured by using CIE illuminant C, T_{850} and T_{1550} are the transmittances at the wavelength of 850 nm and 1550 nm, respectively, and integrated value

means the value obtained by integrating transmittances of every 1 nm in the wavelength from 1100 to 2200 nm. It should be noted that T_{UV} was obtained more specifically as a ratio of ultraviolet light energy calculated by integrating within the wavelength range from 300 to 400 nm of the solar spectrum which transmitted the sample relative to ultraviolet light energy calculated by integration within the wavelength range from 300 to 400 nm having the energy distribution of the solar spectrum at Air mass 2 reported by Parry Moon.

5 Table 2

Examples (single plate)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SiO ₂	70.4	70.2	70	70	69.9	70	70	69.4	69.2	70	69.4	70.2	70	70.2
Al ₂ O ₃	1.6	1.6	1.6	1.6	1.6	1.5	1.6	1.5	1.5	1.6	1.5	1.6	1.6	1.6
Na ₂ O	14.3	14.4	14.5	14.2	14.3	14.3	14.3	14.3	12.5	14.2	14	12.5	14.4	14.4
K ₂ O	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	3	0.5	0.5	3	0.5	0.5
MgO	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	0.4	3.2	3.2	3.2	3.2	3.2
CaO	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.7	12.5	8.8	8.7	8.8	8.8	8.8
TiO ₂	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.10	0	0
T·Fe ₂ O ₃	1.20	1.10	0.98	0.85	0.81	0.81	0.78	0.78	0.78	0.70	0.70	0.902	0.950	0.744
CeO ₂	0	0.20	0.50	0.90	0.91	0.91	0.88	0.88	0.88	1.20	0.65	1.40	1.70	1.40
SO ₃	0.18	0.17	0.17	0.18	0.18	0.17	0.17	0.17	0.16	0.15	0.16	0.18	0.17	0.17
MnO/ mass ppm	40	80	120	150	150	200	200	190	190	250	150	80	40	80
FeO ratio	0.278	0.285	0.28	0.275	0.27	0.288	0.318	0.33	0.349	0.326	0.283	0.27	0.288	0.26
Thickness / mm	1.4	1.6	1.8	2	2.1	2.1	2.1	2.1	2.1	2.3	4	4	4	1.8
Y _A / %	80.3	80.0	80.2	80.3	81.0	80.6	80.6	80.5	80.4	80.5	70.5	72.1	72.0	81.0
T _G / %	60.4	59.5	59.6	59.2	61.4	60.1	59.6	58.9	58.0	58.5	40.4	40.3	44.3	59.5
T _G /Y _A ratio	0.752	0.744	0.743	0.737	0.758	0.746	0.739	0.732	0.721	0.727	0.573	0.560	0.615	0.735
T _{UV} / %	32.8	38.7	39.5	40.0	40.1	40.3	40.3	40.3	40.3	40.3	33.1	32.9	40.1	38.9
D _w / nm	539.0	535.0	530.0	509.0	526.0	516.0	501.0	500.0	505.0	495.8	513.8	495.7	512.6	
P _e / %	4.3	4.3	4.3	2.2	2.2	2.2	2.2	2.2	2.2	2.2	3.3	2.8	4.4	1.5
T ₈₅₀ / %	45.6	44.2	44.1	42.7	44.9	44.8	42.0	41.3	40.2	41.9	45.7	45.6	45.9	47.8
T ₁₅₅₀ / %	57.9	56.4	56.4	55.2	58.8	56.1	57.0	55.1	54.5	54.5	58.8	55.6	59.2	57.3
INT1100-2200	61680	60035	59950	58865	61870	57890	60520	58690	55630	57780	56799	55197	59921	61964

* The units of all components except MnO are expressed in mass %. Y_A: Visible light transmittance

T_G: Total solar energy transmittance T_{UV}: Ultraviolet transmittance D_w: Dominant wavelength P_e: Excitation purity

T₈₅₀: Transmittance at the wavelength of 850nm T₁₅₅₀: Transmittance at the wavelength of 1500nm INT1100-2200: Integrated value of transmittance of every 1 nm in the wavelength from 1100 to 2200 nm

Table 3
Comparative Examples (single plate)

	61	62	63	64	65
SiO ₂	71.7	71.0	70.4	71.5	71.2
Al ₂ O ₃	2.1	1.9	1.5	1.7	2.1
Na ₂ O	13.0	12.9	14.2	12.9	13.0
K ₂ O	0.9	0.8	0.6	0.8	1.0
MgO	3.9	4.4	3.2	3.7	3.6
CaO	8.3	8.6	8.4	6.8	8.1
TiO ₂	0.04	0.08	0.05	0.35	0.07
T-Fe ₂ O ₃	0.10	0.46	0.75	0.61	0.86
CeO ₂	0	0	0.85	1.60	0.10
SO ₃	0.2	0.18	0.19	0.15	0.18
MnO/ mass ppm	60	190	200	40	130
FeO ratio	0.242	0.278	0.256	0.367	0.261
thickness/ mm	2.1	2.1	2.1	2.1	2.1
Y _A / %	91.0	58.8	81.9	81.7	79.5
T _G / %	99.2	71.7	63.2	62.5	61.7
T _G /Y _A ratio	1.090	1.219	0.772	0.765	0.776
D _w / nm	519	511	526	536	514
T ₈₅₀ / %	86.6	60.3	46.8	47.5	46.9
T ₁₅₅₀ / %	88.2	69.8	57.8	58.3	59.4
INT1100-2200	97750	75390	64222	62770	63290

* For the notation of each section, Table 2 is to be referred.

The desired properties are obtained in Examples 1 to 14, while the desired properties are not obtained in Comparative Examples 61 to 65. For 5 example, with respect to the integrated value of the transmittance in the wavelength region of 1100 to 2200 nm, that of each Example is 62000 or less, but that of each Comparative Example exceeds 62000. Moreover, in Examples 1 to 10, the values of T_G / Y_A are 0.76 or less, which are different from Comparative Examples 61 to 65, although the glass sheets thereof are thin. Consequently, it is understood that the whole composition is adjusted 10 properly in each Example.

According to equations (1) and (2), when the thickness *t* is 2.1 mm, T-Fe₂O₃ should be adjusted to be within 0.75 to 0.85% and the content of CeO₂

should be adjusted to be 0.3 to 1.3%. In this case, the preferable FeO ratio is from 0.275 to 0.35. No composition of any Comparative Example satisfies these conditions. In contrast, the composition of each Example except Example 5 satisfies equations (1) and (2) regardless of the thickness, and the 5 FeO ratio also falls in the above range.

The two of the glass sheet obtained above were bonded together using an interlayer film (poly(vinyl butyral) film) to form a laminated glass. However, laminated glasses of Comparative Examples 75 and 76 were produced using the glass sheets shown in Table 6.

10 The properties of the laminated glasses measured are shown in Tables 4 and 5.

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Table 4

Examples (laminated glass)

	21	22	23	24	25	26	27	28	29	30	31	32
Combination of glass plate	(2)+(3)	(3)+(3)	(3)+(4)	(4)+(4)	(5)+(5)	(2)+(3)	(3)+(3)	(3)+(4)	(4)+(4)	(5)+(5)	(3)+(5)	(10)+(10)
Thickness/mm	1.8+1.6	1.8+1.8	1.8+2.0	2.0+2.0	2.1+2.1	1.8+1.6	1.8+1.8	1.8+2.0	2.0+2.0	2.1+2.1	2.1+1.8	2.3+2.3
Y _A / %	70.1	70.1	70.2	70.5	71.0	70.4	70.6	71.4	70.7	70.6	71.9	71.1
T _G / %	42.4	42.1	41.8	41.7	40.9	39.8	39.3	44.2	43.0	41.6	41.9	40.8
T _G /Y _A ratio	0.605	0.601	0.595	0.591	0.576	0.565	0.557	0.619	0.608	0.589	0.583	0.574
T850 / %	21.6	21.5	20.3	20.1	19.8	18.3	17.1	24.2	22.4	19.5	20.6	20.6
T1550 / %	34.9	34.8	33.4	33.2	33.4	30.8	27.9	36.6	34.7	32.5	33.7	33.8
INT1100-2200	32950	32860	32370	32210	30520	28330	25830	33420	32520	31450	32320	32350
T _{tf} / %	-	40.0	-	-	39.6	-	-	-	-	40.0	39.9	

* For the notation of each section, Table 2 is to be referred, except Trf: Transmittance for thermal feeling

Table 5
Comparative Examples (laminated glass)

	71	72	73	74	75	76
Combination of glass plate	(63)+(63)	(62)+(62)	(61)+(65)	(62)+(64)	(81)+(81)	(82)+(82)
Thickness/mm	2.1+2.1	2.1+2.1	2.1+2.1	2.1+2.1	2.2+2.2	1.8+1.8
Y _A / %	73.9	78.3	78.8	75.9	71.4	72.2
T _G / %	45.5	53.6	57.0	49.4	43.0	44.1
T _G /Y _A ratio	0.616	0.685	0.723	0.651	0.602	0.611
T850 / %	27.2	37.3	-	-	-	-
T1550 / %	37.7	47.4	-	-	-	-
INT1100-2200	34640	43090	-	-	-	-
Ttf / %	-	-	-	-	45.0	46.0

* For the notation of each section, Tables 2 and 4 are to be referred.

Table 6
Compositions of single plates for laminated glasses of Comparative Examples

	81	82
SiO ₂	71.73	71.73
Al ₂ O ₃	0.12	0.12
Na ₂ O	13.78	13.78
MgO	4.00	4.00
CaO	8.64	8.64
Cr ₂ O ₃	0.0003	0.0003
La ₂ O ₃	0.0009	0.0009
SO ₃	0.14	0.14
TiO ₂	0.017	0.016
T-Fe ₂ O ₃	0.776	0.834
CeO ₂	0.89	0.913
FeO ratio	0.243	0.268

* The content of each component is expressed in mass %.

5 The desired optical properties are obtained in Examples 21 to 32.

INDUSTRIAL APPLICABILITY

The present invention provides a near-infrared absorbent green glass composition which reduces the thermal feeling that affects comfort in cars or rooms and has excellent optical properties totally, and a laminated glass using 5 the glass composition. The preset invention thus has a high utility value in the technical field of window glass as well as in other technical fields.